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WASTE MANAGEMENT IN A LUNAR BASE

TASK 5 SUMMARY REPORT

A TOP-LEVEL SYSTEM INTEGRATION

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prepared for

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WASTE MANAGEMENT IN A LUNAR BASE

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A TOP LEVEL SYSTEM INTEGRATION

1. INTRODUCTION

Long term human habitation in space requires an autonomous life support system (NCOS, 1986; Ride, 1987; NASA, 1988). An Engineered Closed Ecosystem (ECES) can provide autonomy through integration of the human module with the support plant and animal modules and a waste management system (WMS). The role of the WMS is to treat metabolic wastes (or output metabolic elements) for reuse. Achievement of the integration depends upon combining physical/chemical and biological subsystems into an engineered bioregenerative system. An operational bioregenerative life support system will lead to acceptable autonomy in space habitation by minimizing resupply from Earth.

An effort was undertaken to develop a top-level system integration by identifying the interfaces and interactions among the human module, the support plant and animal modules and the WMS. To achieve the integration the WMS must consist of the following three subsystems:

(1) raw material sorting/storage;

(2) raw material processing;

(3) processed materials storage/supply.

In addition, the following support units are reuqired:

(1) control/monitoring (C/M) for each module and WMS subsystems;

(2) backup storage/supply of input metabolic elements (or consumables);

(3) nutrient recovery for the plant module;

(4) nutrient backup storage/supply for plant module;

(5) light for the plant module;

(6) residual waste storage/disposal.

2. ENGINEERED CLOSED ECOSYSTEM

The steps involved in the development of an ECES are:

(1) identification of the category and characteristics of each input/output metabolic element for/from every module;

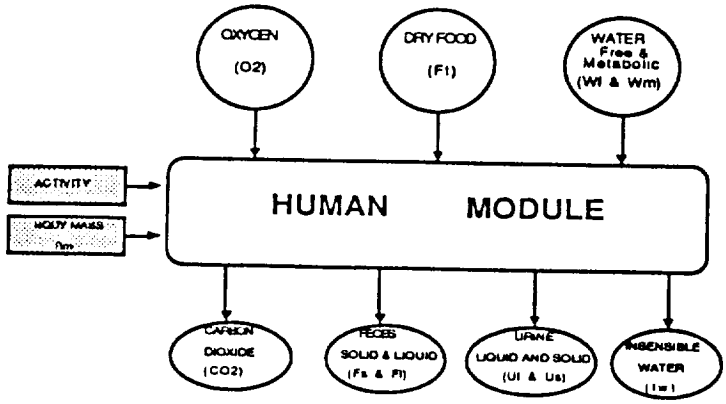
(2) determination of the metabolic massflow rate of each input/output element for/from every module;

(3) identification of waste treatment processes and associated enabling technologies capable of treating/recycling the output metabolic elements for utilitarian reuse.

Completion of these steps provides the input for estimating the capabilities of an ECES to accommodate a wide range of metabolic massflows. Each output metabolic element is essentially a waste product and, at the same time, represents a raw material requiring treatment prior to its reuse.

3. MODULE INTERFACES

Input/output metabolic elements associated with each module are shown in Fig. 1. Each output metabolic element must undergo some type of physical/chemical and/or bioregenerative processing (or treatment) prior to its reuse as an input metabolic element. Physical/chemical treatment ranges from simple disinfection of humidity condensate for use as potable water to complex separation and processing of human feces to be utilized as a plant nutrient. Bioregenerative treatment involves the conversion of output metabolic elements to usable input metabolic elements. An example is the plant module consuming carbon dioxide produced by the human and animal modules and supplying oxygen to the human and animal modules.



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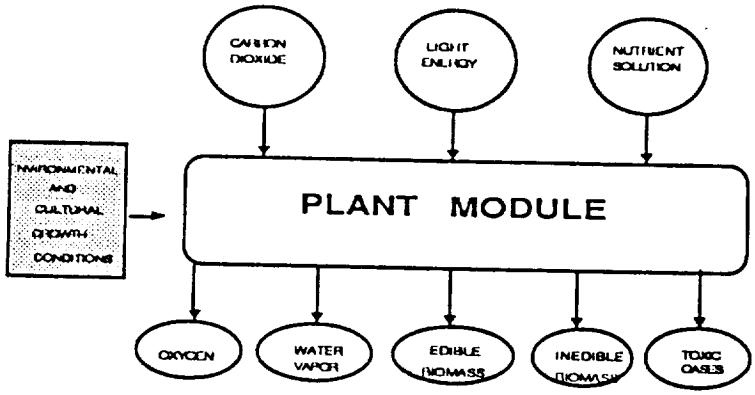

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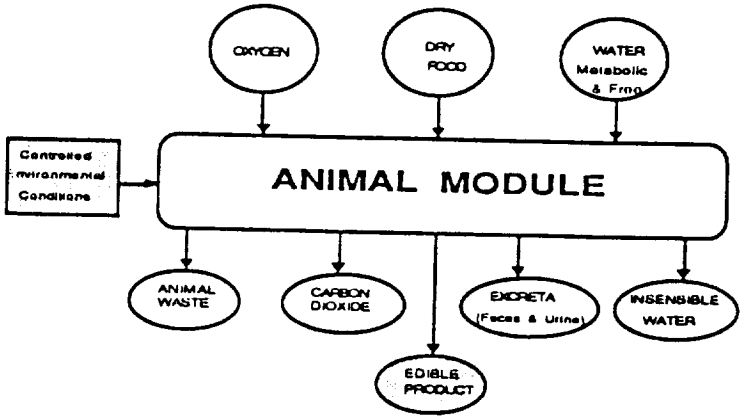

(c)

Fig. 1 Input/output metabolic elements for the three modules and associated control units.

4. TOP-LEVEL DIAGRAM

An attempt to integrate the human, plant and animal modules with the WMS is depicted in the top-level diagram given in Fig. 2. The goal of the top-level integration is to furnish a qualitative view into how to collect, process and reuse raw materials as input metabolic elements. Information compiled in previous reports which delineated metabolic massflow rates (MMR's) and reviewed waste treatment processes and associated enabling technologies (Sadeh, et al., 1989a; b; c; d) provide the foundation for conducting the top-level integration. Continuous control/monitoring of temperature, pressure, humidity, chemical composition and massflow rates is required for each module and WMS subsystem. All the support units for each module and WMS subsystem are shown in Fig. 2 to indicate their input and/or output role. The overall functions of each WMS subsystem are briefly discussed.

4.1 Raw Material Sorting/Storage

Each raw material must be sorted prior to processing according to its physical/chemical properties (e.g., gas, solid, liquid, composition) regardless of origin. Storage of the sorted raw materials ensures continuous massflow rates to the processing subsystem. Gases include O_2, CO_2, N_2 and water vapor. Human feces and urine must be consolidated with animal excreta. Animal offal (i.e., blood, feathers, bones and viscera) must be collected with inedible plant biomass. Edible biomass from the plant and animal modules must be combined.

4.2 Raw Material Processing

The raw materials must be processed by appropriate enabling technologies as required for their reuse. Processed raw materials include:

(1) oxygen, carbon dioxide, nitrogen;

(2) potable water from water vapor;

(3) nutrients from solid and liquid processing,

which flow to the processed materials storage/supply subsystem. All metabolic massflows from the raw material processing subsystem to the storage/supply subsystem are denoted with a heavy line in the top-level diagram in Fig. 2 for identification sake. Nutrients from the raw material processing subsystem flow to the nutrient recovery support unit for further processing, if required, prior to being directed to the plant module. Unusable residual wastes and volatile gases (e.g., phytotoxic gases) flow to the residual waste storage/disposal support unit.

4.3 Processed Materials Storage/Supply

Required metabolic inputs to each module are furnished from the storage/supply subsystem. Control of the supply of input metabolic elements to the three modules is performed by the storage/supply subsystem. The backup storage/supply support unit serves to supply consumables when demand exceeds supply of processed raw materials and for emergency purposes. Nutrient backup storage/supply and light support units are required for the plant module to ensure optimum growth conditions.

5. CONCLUDING REMARKS

Integration of the input/output metabolic massflows to/from each module with the WMS is described in terms of a top-level diagram. The proposed top-level diagram is constrained, at this stage, to qualitatively showing the interfaces and interactions among the human, plant and animal modules, the raw material sorting/storage, raw material processing and processed materials storage/supply subsystems of the WMS and the support units.

Quantification of the metabolic massflows was not considered as details of the overall system configuration must first be defined. A range of massflow rates of each input/output metabolic element must be determined prior to hardware selection and development. Future research must hence be directed to develop an expanded version of this top-level diagram which quantifies each input/output metabolic element in the ECES with acceptable ranges and resolution. The quantification will permit sizing of each WMS subsystem.

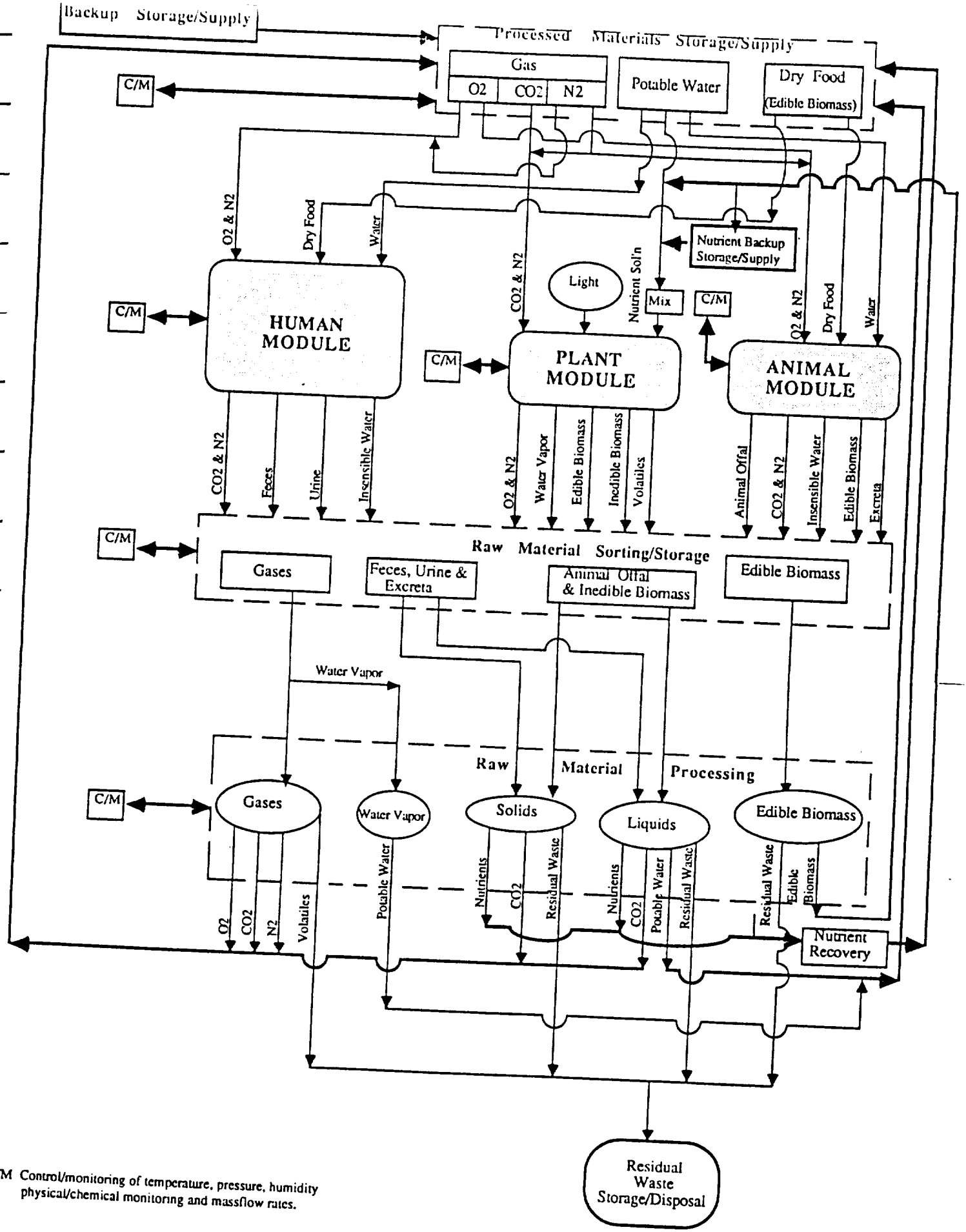

Fig. 2 Top-level integration diagram of an ECES.

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